

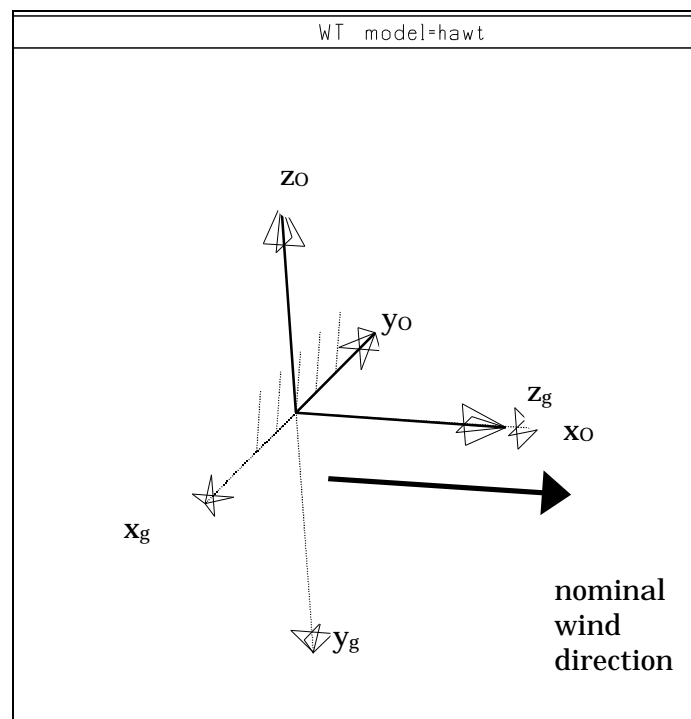
Chapter 3 Model Description

3.1 Introduction

Before describing the details of the WT menus and panels and input data, it may be helpful to understand the overall organization of the *hawt* model and to get a feel for how it goes together. The sections that follow describe some of the basic layouts, sign conventions and approaches used in WT, as well as the design of the flexible tower and rotor blades, and how the aerodynamics are set up. The information in this chapter should agree with the five example cases described in more detail in later chapters.

3.2 WT Coordinate Systems

Like any ADAMS model, *hawt* has an associated inertial reference frame known as the *ground* part, with reference axes x_g , y_g and z_g . The *hawt* model also has its own, separate base frame that is used for model construction and for the aerodynamics calculations. In this frame, which is associated with the ground marker O , $+z$ is “up” and $+x$ is nominally downwind. In earlier versions of WT, these two frames were coincident, but that led to serious computational problems with Euler angle singularities. Shifting the O marker as shown has eliminated those problems.



Note that all aerodynamic calculations in the AeroDyn subroutines are referenced to the O marker, so this change did not effect them. Gravity force, however, is defined in global coordinates and should normally have a positive y component.

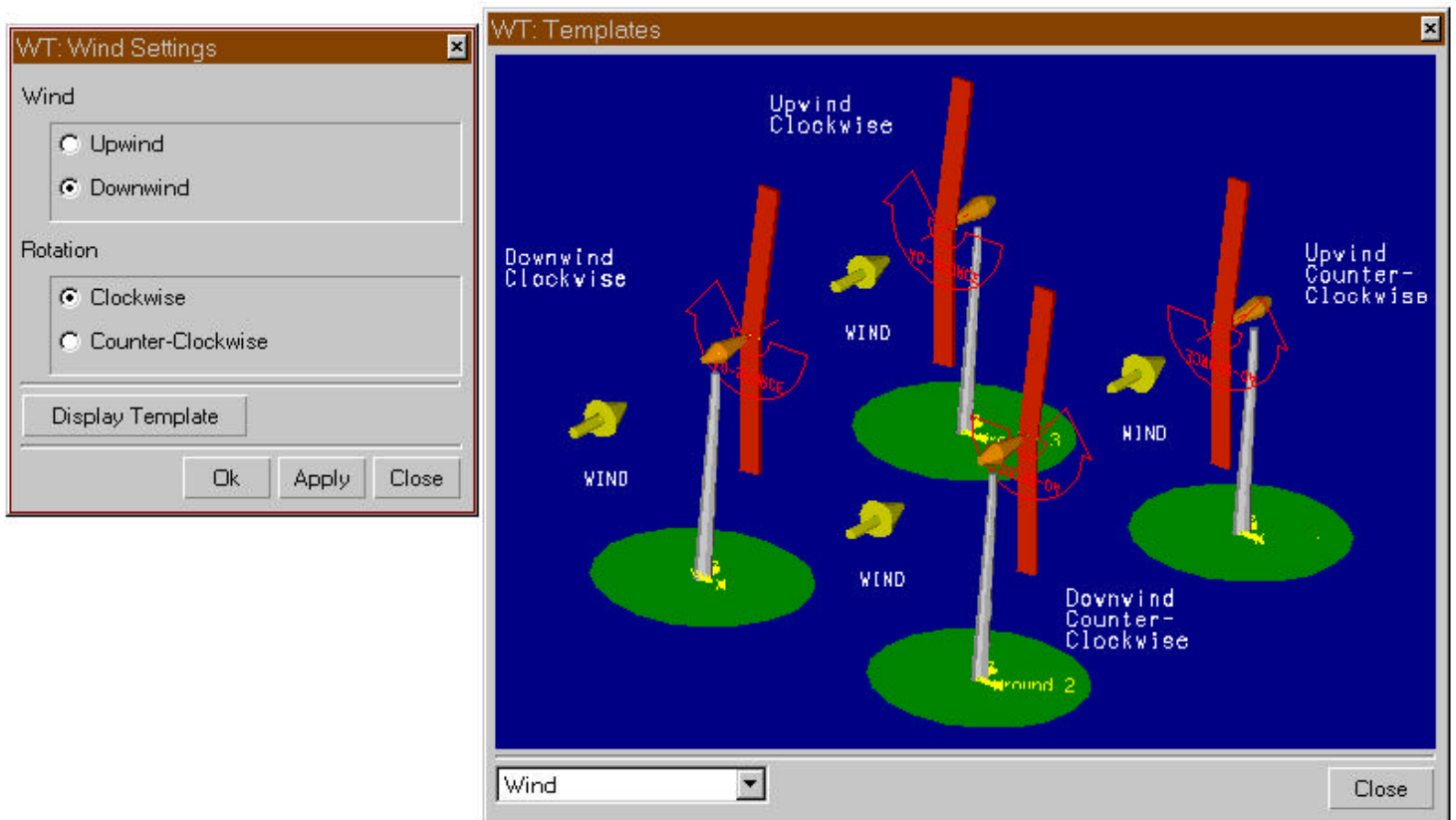
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3.3 Selection of Rotor Orientation and Direction of Rotation

In ADAMS/WT you must select, prior to construction of your model rotor, the direction of rotor rotation and whether the rotor is an upwind or downwind configuration. This is done through a new first selection on the main WT menu, Wind/Rotation Setup.



Selecting this will bring up the following template and associated panel :

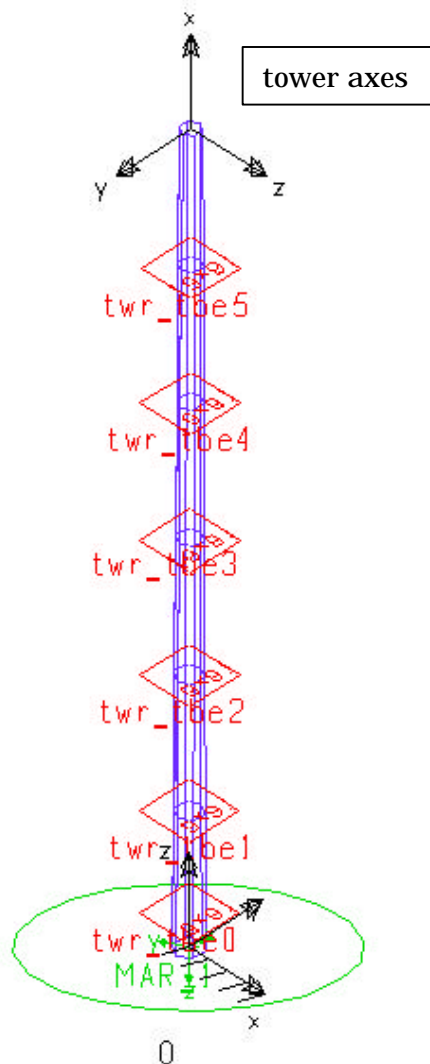


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ADAMS/WT defaults to the Downwind/Clockwise configuration, which was the only choice in previous versions. You should choose one of the four choices shown. The direction of rotation is taken looking downwind toward the rotor as shown. This choice will be automatically reflected in many other elements throughout the rotor construction.

3.1 Tower Construction

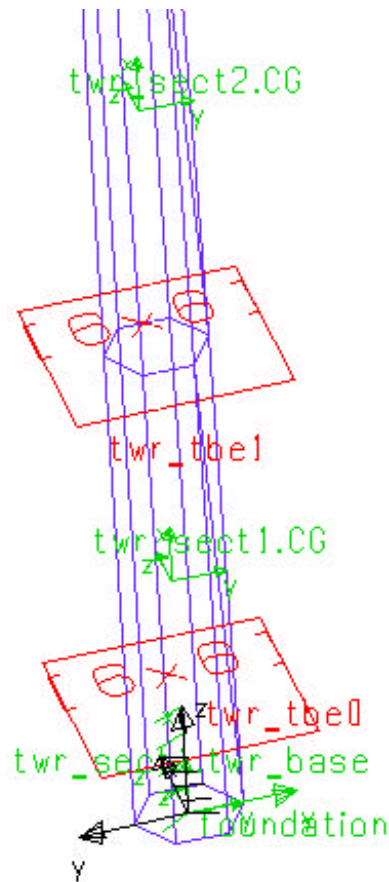
In ADAMS/WT, the support tower is an aggregate element which is modeled, regardless of its actual construction, as a beam-like structure using the tapered beam and tapered part low-level elements. Details of those elements can be found in following chapters. Like the ADAMS BEAM element, the tower long axis is along the *local* +x direction of the tower PARTs and FIELDS (which is +z in the model base frame, i.e. with respect to the *O* marker, and -y in the *ground* coordinates).



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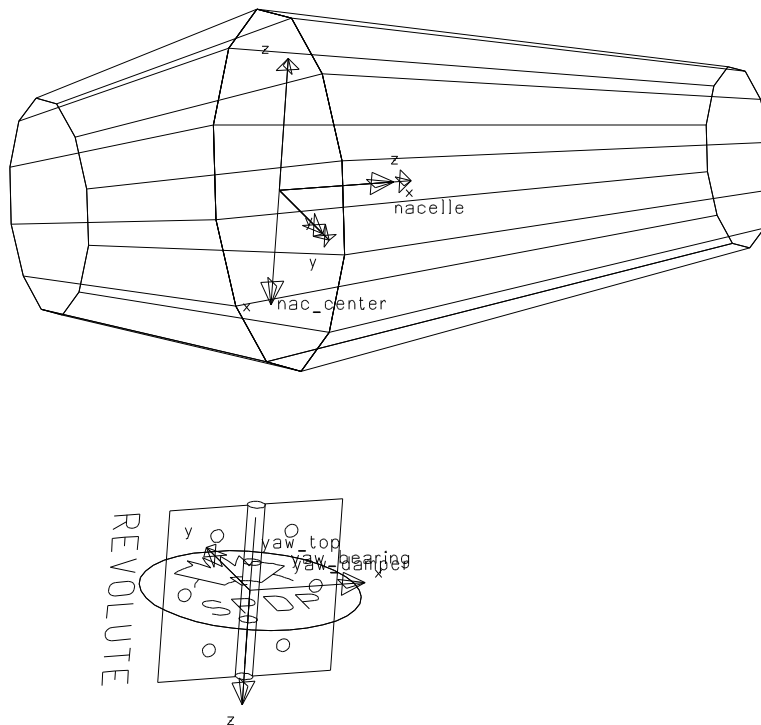
Each pair of parts in the tower is connected by one of the special WT tapered beam FIELD elements (see section 4.1), running between the part centers-of-gravity. Note that in View 9.1, the center-of-gravity markers no longer have the "CG ball" attached. The bottom-most part is connected to *ground* using a half-length WT tapered beam FIELD element. This is shown in the following figure.

Tower parts are named *twr_sect#*, numbered from the bottom up starting with 1. The special tapered beam FIELD elements are named *twr_tbe#*, again numbered from the bottom up, starting with 0. Each of these is arranged with the J marker for the FIELD on the bottom and the I marker on the top. For example, for *twr_tbe0*, the J marker is *ground.foundation* and the I marker is *twr_sect1.CG*. For *twr_tbe1*, the J marker is *twr_sect1.CG* and the I marker is *twr_sect2.CG*.

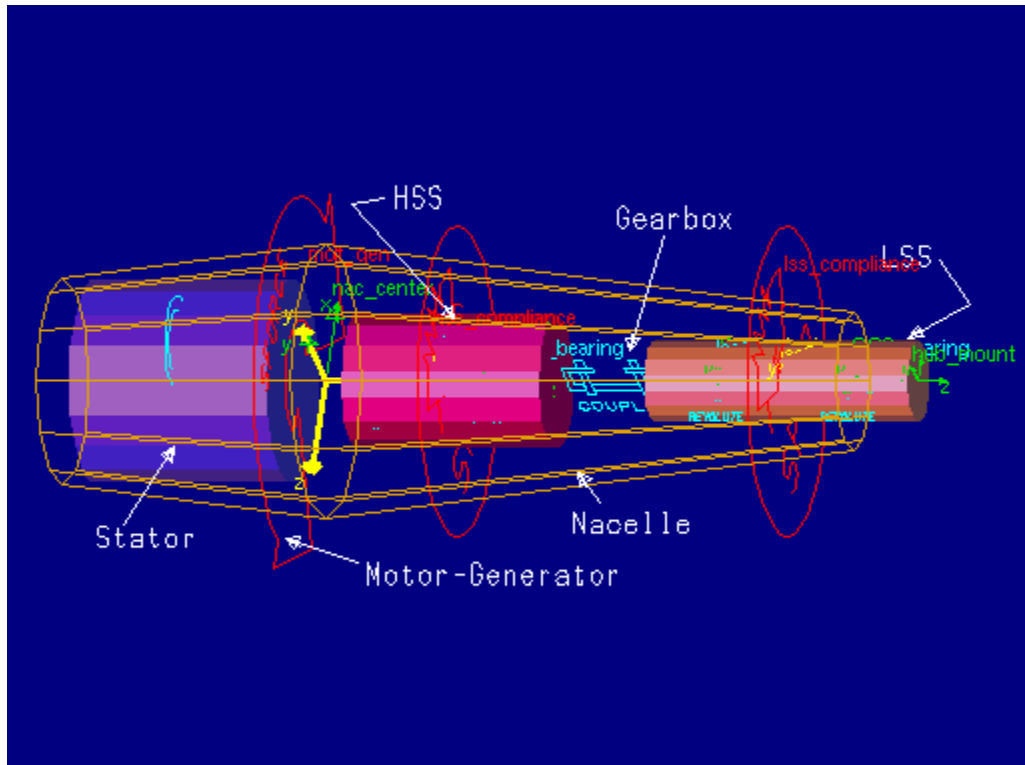


3.2 Nacelle and Power Train Construction

The nacelle is treated rather simply in ADAMS/WT. It basically serves as a platform on which to mount the power train and to connect to the tower. It consists of only one part, *nacelle*, which is connected to the tower with a revolute JOINT call *yaw_bearing* and a rotational SPRING-DAMPER called *yaw_damper* or simply with a fixed JOINT. The normal downwind configuration is shown in the figure below. More important to note is the MARKER at the part axes called *nac_center*. While the part axes are useful in defining the *nacelle* inertias, the *nac_center* MARKER's z-axis is used by default to define the power train axis of rotation. That is, the z-axis of *nac_center* will also be the rotor shaft axis.



The power train consists of multiple ADAMS entities, including the generator body (a PART), the motor-generator (a rotational SFORCE), high-speed and low-speed shafts (multiple PARTs) and the gearing, if any (a COUPLER). All the parts are arranged with their +z-axes aligned with the *nac_center* z-axis (pointing toward the hub for a downwind rotor and away from the hub for an upwind rotor), and are attached to the *nacelle* with appropriate JOINTs. Depending on the configuration of your particular rotor, some of these components may not be needed in the model. This power train template can be displayed in WT when creating the different parts of the system.

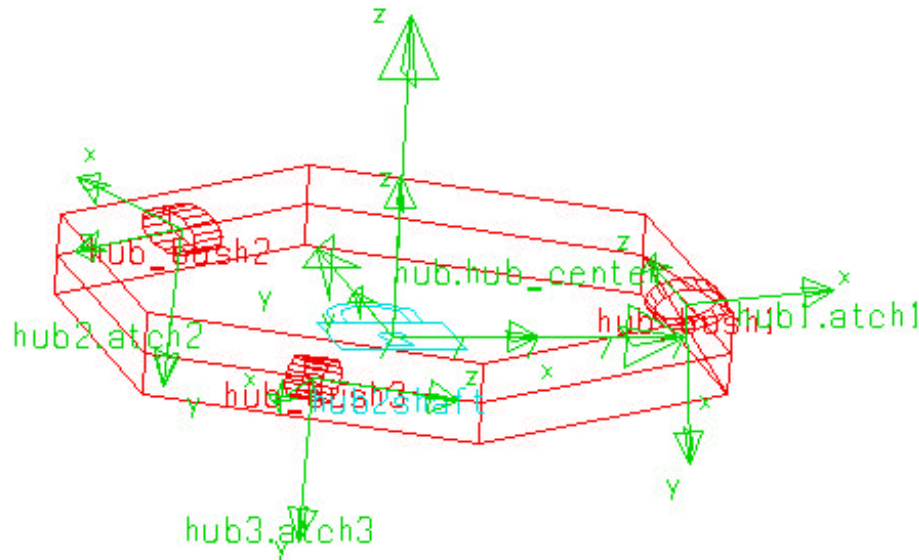


3.3 Hub Construction

WT allows for eight different hub variations design to cover most of the existing and proposed hub designed. You can chose between 2-bladed teetering and 3-, 4- or 5-bladed rigid hubs. You can optionally add limited flexibility (at the blade attachment point) to any of the choices. All of the hubs have a *hub_center* MARKER at the center which will exactly overlay the *hub_mount* MARKER on the end of the low-speed shaft when the hub is attached.

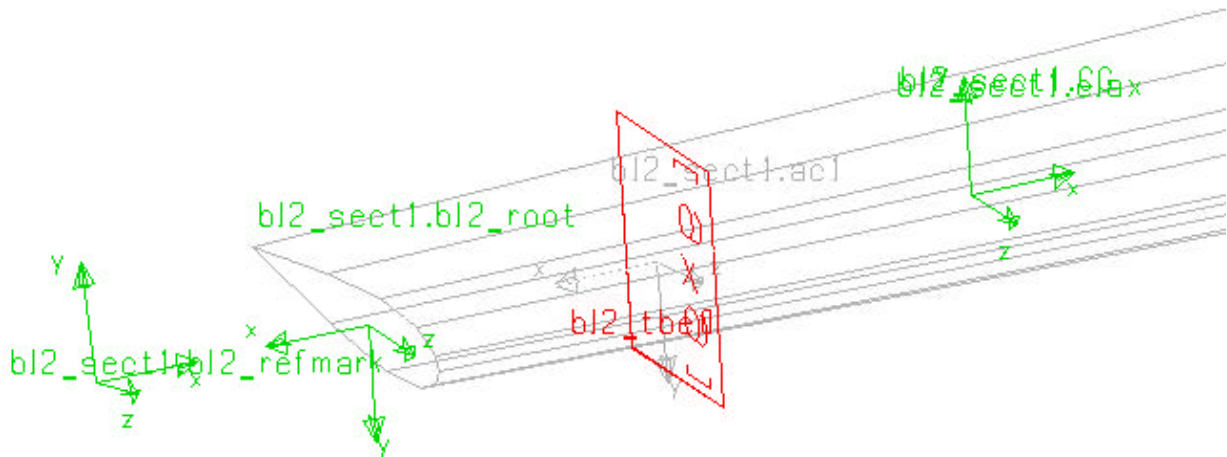
The +z-axes of these MARKERs points down the shaft axis along with the power train components. At each of the blade attachment points (2, 3 or 4) there is a special MARKER called *atch#*, where the numbering corresponds to the blade numbering. These attachment markers are important because the blade pitch is defined with respect to them when the blades are attached to the hub. The +x-axes of these markers point radially outward (for clockwise rotating rotors) or inward (for counter-clockwise rotating rotors), and pitch is defined about them. Also, when a flexible hub is used, the flexible BUSHING elements used to localize the compliance are also located at these spots.

An example 3-bladed, flexible, clockwise-rotating hub is shown below.



3.4 Blade Construction

In WT there are two different types of rotor blades, fully flexible and rigid/hinged. The fully flexible blade is an aggregate element, much like the tower, and is also modeled as a beam-like structure using the tapered beam and tapered part low-level elements. The rigid/hinged blade is a one- or two-part aggregate element with an optional hinge and spring-damper between the parts. This corresponds to the classic rigid flap-only blade often used as a simpler analytical approximation in other analyses.

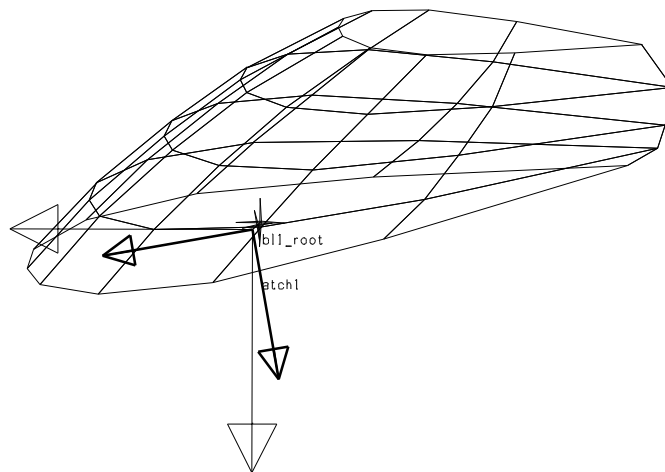


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Regardless of which type of blade is used, the blade's long axis (i.e. radial axis) is outward along the *local* x direction of the blade PARTs and *structural* markers, with the +z direction is toward the leading edge. For the *root* and *aerodynamic markers*, however, the +z direction is toward the leading edge and the +y direction is toward the pressure side (nominally upwind). This means that for a rotor which rotates clockwise looking downwind (which is the WT default) the x-axes point outward, while for a rotor which rotates counter-clockwise looking downwind, the x-axes point inward.

The blade twist, both aerodynamic and structural, is defined with respect to a reference marker called *bl#_refmark*, where the # is replaced by the blade number. Because of the way the blade is attached to the hub, twist is positive about the +x axis of the reference marker regardless of the rotor configuration, so that positive twist is out of the wind.

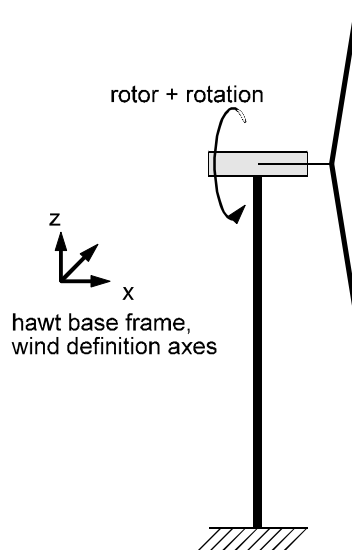
When the rotor blade is attached to the hub (see ROTOR_BLADE RELOCATE command in section 5.6.4), the **pitch** is defined as the angle from the z-axis of the attachment marker on the hub to the z-axis of the attachment marker on the blade, with the positive sense about the x-axis of the attachment marker on the hub. Regardless of the rotor configuration, positive pitch is out of the wind, just like twist. In the clockwise-rotation figure below, the smaller *bl1_root* marker is highlighted and is set at a -10° degree pitch angle with respect to the larger *atch1* marker. This is explained in more detail in section 5.6.



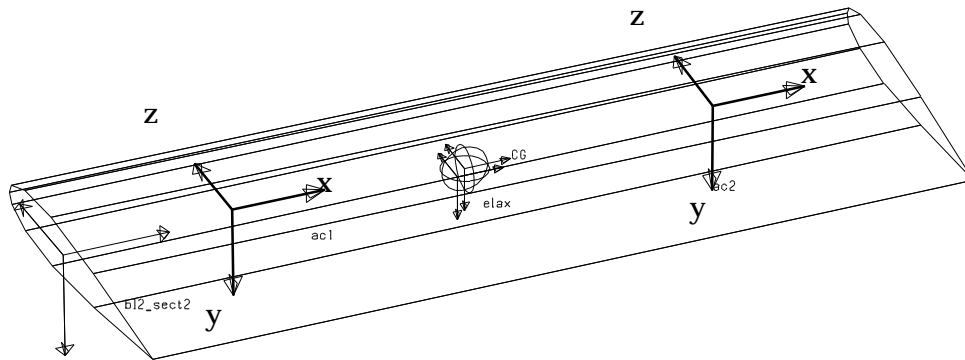
3.5 Aerodynamics

Aerodynamics, either the simple, linear steady aerodynamics or the complete 2-D, nonlinear, unsteady aerodynamics from the AeroDyn package, can be automatically added to a blade in WT very simply (see AERODYNAMICS menu). The automation, however, hides very strict rules for the orientation and placement of the aerodynamic control point markers and the wind definition coordinates.

As mentioned previously, in ADAMS/WT, the default rotor configuration is downwind with clockwise rotor rotation looking downwind, i.e. positive about the base frame x-axis. You can also choose counter-clockwise rotor rotation and/or upwind configuration. WT will make the appropriate changes to the blades, attachments, hub and drive train to properly reflect your choice. This is the default configuration:



With WT, you have a choice of putting 0, 1 or 2 aero markers on each blade section, and you can define the number of aero markers per section either once for the whole blade or individually on a section-by-section basis. (You might use 0 markers for a section of blade which is structurally active but aerodynamically inactive, such as a flex-beam.) When WT adds aerodynamic control markers to a rotor blade section, it automatically puts them at the Gaussian integration points and orients them correctly, as shown in the two-point. Clockwise-rotating blade section shown here. In this figure, the *ac2* MARKER has a greater twist angle than *ac1*.



When using the AeroDyn subroutines, wind components (including turbulence, wind shear and tower shadow) are defined in the WT base frame shown above in section 3.2. When using the simpler, linear aerodynamics routines, the wind components are defined using a dummy VFORCE element called *wind*, which is attached to a dummy part called *wind_dummy_part*, that is fixed to the ground. By default, the *wind* axes are also aligned with the WT base frame as shown here.

